The Next Stage of Road Traffic Education: A Mixed Reality Bicycle Simulator to Improve Cyclist Safety

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Abstract: When involved in an accident, vulnerable road users, such as cyclists, often get injured more heavily than people inside vehicles. We want to study the effects of new infrastructural concepts and technologies such as head-up displays for cyclists and the possibilities brought by automated vehicles and smart, connected traffic, on actual cyclist road safety. Using a mixed reality simulation allows developing, testing, and evaluating new concepts within the safety of a simulation. Additionally, we plan to investigate how children can be prepared better for cycling during traffic safety education. Our bicycle simulator can be used in a CAVE, with a VR headset, or as a standalone PC simulation, to explore the different aspects of our research on human factors and cycling.

Keywords: Mixed Reality Simulation, Cyclist Safety, Head-up Displays, Human Factors

1 Introduction

Like pedestrians, cyclists lack a protective chassis around them and are therefore vulnerable road users (VRUs). The main cause of accidents is inattentiveness to the environment. As the driving task itself happens more and more subconsciously, the level of alertness and awareness decreases over time, which leads to overlooking possible hazards.

We hypothesize that cyclists can benefit from a mixed reality (MR) bicycle simulation with which they can train behavior in dangerous traffic situations in the "safe zone" of a simulation environment. We also assume that simulating cycling in MR can help, e.g., while learning cycling or by regaining higher alertness in traffic and awareness of possible accidents, but also for the assessment of new safety concepts for cyclists. Furthermore, new passive and active safety measures, such as (re)construction of bicycle lanes, or the integration of head-up displays (HUDs) to display warnings to the cyclist, can be assessed. In the following, we present our bicycle simulator framework.

2 Research Focus

In the scope of our research, we want to investigate two aspects which could increase road safety for cyclists: (1) how can children benefit from "virtual" traffic education and (2) how the general public responds to novel warning systems displayed on a HUD. Furthermore, we want to investigate the practicability of a MR simulator as a tool for traffic safety research.

Veröffentlicht durch die Gesellschaft für Informatik e.V. 2020 in B. Weyers, C. Lürig, D. Zielasko (Hrsg.):
GI VR / AR Workshop 2020, 24. - 25, September 2020, Trier.

http://dx.doi.org/10.18420/vrar2020_31

We expect that children who train hazardous situations in the safety of MR simulation can recognize and react to dangers faster. To ensure that children benefit from such modules, we will cooperate with junior traffic training centers. Matviienko and colleagues investigated the impact of uni- and multi-modal warning cues for child cyclists on collision avoidance [MAB+18], as well as on lane-keeping [MAB+19], and navigation [MAE+19]. In all user studies, they found that additional information can increase the children's performance.

The advent of automated driving and connected traffic also provides opportunities for VRUs to increase road safety. Von Sawitzky et al. [vWL+20] investigated whether cyclists benefit from using a HUD in a futuristic setting with fully automated vehicles. In their pilot VR study, they investigated concepts that could increase safety when crossing an intersection. Their findings show that people are interested in HUDs for cyclists and believe that such a technology can improve the cycling experience and cyclist road safety.

We want to find ways to increase the attentiveness of cyclists and their awareness of the environment. One possible approach is to use HUDs. These were introduced to keep vehicle drivers focused on the road by presenting information directly in their line of sight on the windshield, to mitigate distraction while driving. HUDs could also contribute to a more safe cycling experience by indicating potential dangers. Even when using a HUD, the cyclist must be able to perceive the environment at any time. Thus, visual content must not occlude a substantial part of the FOV. Additionally, the content displayed should be easily comprehensible and non-distracting, to keep the cyclist focused on the road and environment traffic. For a HUD prototype, it is feasible to resort to AR glasses. However, for outdoor tests, the contrast of those devices is too low, and they cannot be worn with a helmet at the same time. In recent years, HUDs for cyclists also became accessible[1], displaying information, such as current velocity, heart rate, and navigation cues on glasses or on a small display clipped to the helmet.

3 Technical Setup of the Bicycle Simulator

Our bicycle simulation was developed with Unity 3D and can be used with three different setups: on a *PC* in a game-like manner, or with a *VR headset* or a *CAVE*. For the *VR headset* and the *CAVE* setting, we use a bike on a roller trainer with additional support in front to increase stability. An overview of the simulator setup is shown in Figure 1.

3.1 Bicycle Movement

The bicycle movement depends on the speed input, handlebar or body tilt input, or the mouse input (signals 2 to 4 in Figure 1). In the *VR headset* and *CAVE* setups, the user can accelerate/decelerate by actively treading and braking. For speed assessment, we placed a HTC Vive Tracker in between the spokes of the rear wheel. However, the user's feet and the roller trainer occluded the tracker, which lead to a high drift and loss of signal. Therefore,

[1] `www.o-synce-shop.de/head-up-display/117/usee`, `everysight.com/de/produkt/raptor-eu/`

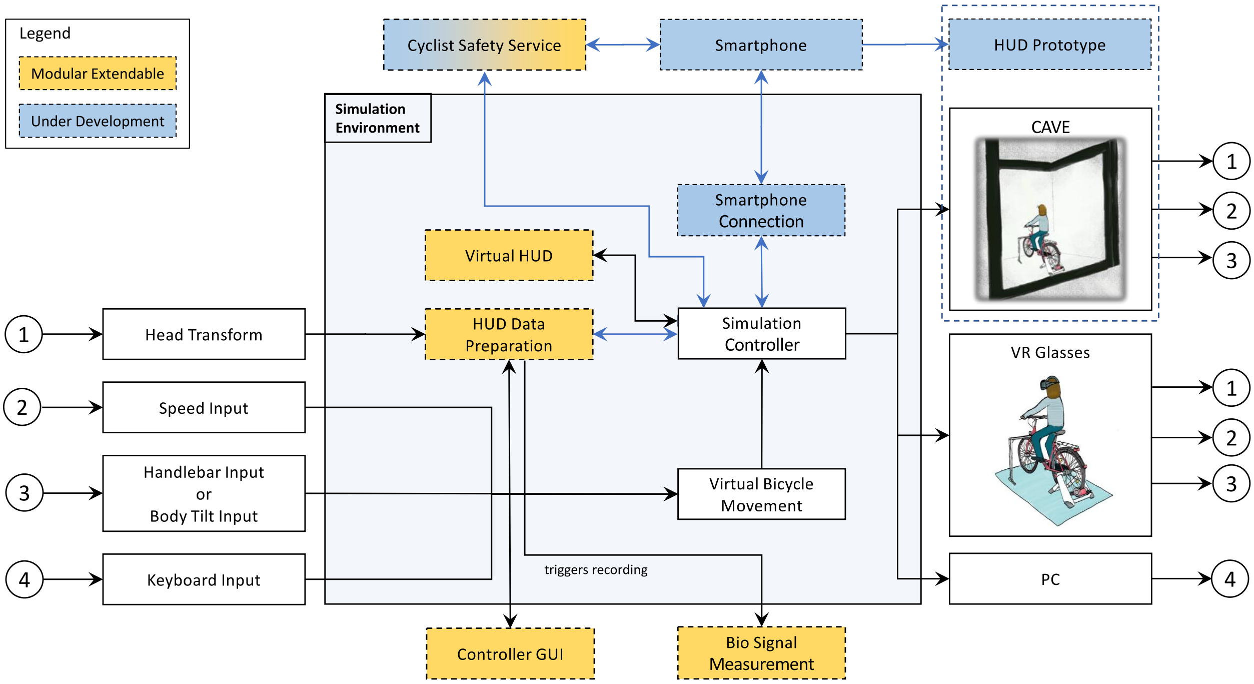

Figure 1: Overview of the bicycle simulator. The blue-colored parts are under development. The features of the orange-colored segments can be extended in a modular fashion.

we moved the tracker to a third wheel, with direct contact with the rear wheel. The steering or tilting angle can be obtained from HTC Vive Trackers placed either on the bike's steering axle or on the user's upper body. The positioning of the virtual HUD depends on the head position and rotation of the user (signal 1) obtained from head tracking. Signals 1 to 3 are used in the *CAVE* and the *VR headset* setting. In the *PC* setting the cycling velocity can be modified by scrolling the mouse wheel, and the bicycle tilt by moving the mouse along the horizontal screen axis.

For the *VR headset* setting, we use a HTC Vive Pro and four base stations (Valve Index, two in the front and two in the back of the bike). Our university's CAVE uses the infrared-based tracking system ART DTrack.

3.2 Simulation Controller

The *Simulation Controller* component distributes the data between the different instances. Additional, informative data for the cyclist can be displayed in all three settings on a virtual HUD in the simulation, or on a HUD prototype within the *CAVE* setting. Examples for displayed information are warnings, current driving velocity, or navigation hints. For example, a route can be selected via a smartphone, which sends a request to a server providing the *Cyclist Safety Service*. We use customized maps of the simulated environment created with *Java Open Street Maps*[2]. During this research project, the warning features of the *Cyclist Safety Service* will be extended further. Additional to the core features of the simulation, the measurement of biosignals, such as ECG or galvanic skin response (GSR), can be integrated.

[2]https://josm.openstreetmap.de/

To control different simulation scenarios, a *Controller GUI* allows the selection ofs the type of information displayed on the HUD, and which output device to use. Additionally, different conditions and settings for user studies can be selected.

3.3 Safety Measures

Although we use a static bicycle, the users of our simulation setup actively tilt their bodies. Thus, we took safety measures to protect them from accidental falls. In the lab-settings (*CAVE* and *VR headset*), users are secured by wearing a climbing harness, which is suspended on an indoor crane. When using the *VR headset* setting outside the lab (e.g., at schools), a supervisor has to monitor the user's activity closely.

4 Summary

In this paper, we introduced our bicycle simulator setup. It can either be used in a *CAVE* or with a *VR headset*, both combined with a physical bike, or with a game-like control on a *PC*. In the future, we plan to perform user studies to evaluate new warning systems for cyclists and develop modules for traffic safety education.

Acknowledgments

This work is supported under the "Innovative Hochschule" program of the German Federal Ministry of Education and Research (BMBF), Grant No. 03IHS109A (MenschINBewegung).

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